



## **On the Impact of the Assimilation of Nacelle Winds and Yaw Angles With WRF-FDDA and WRF-DART for Short-Term Wind Energy Predictions**

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# On the Impact of the Assimilation of Nacelle Winds and Yaw Angles With WRF-FDDA and WRF-DART for Short-Term Wind Energy Predictions



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## Goal: improve wind predictions for wind farms

Several kinds of observations are used today in operational NWP models for improving the analyses used by models. With the ongoing numerous offshore deployments of wind farms, a **new set of measurements** becomes available: wind speeds measured on the nacelle of a wind turbine and turbine yaws, which are both used by the turbine control system for optimal operation of the wind turbine. We intend to find the best way to assimilate this data set.

## Accuracy of wind forecasts is important because

- Transmission system operators and wind farm operators trade power on energy markets based on wind forecasts at turbine locations. Deviations from the bid power result in penalty costs.
- Grid management
- Wind farm maintenance

### Nacelle winds:

- sonic anemometer measures wind **behind rotor**
- 70 m above sea surface
- Turbines downwind are in a wake and experience lower wind speeds.
- Turbine yaws can have offsets
- Data access often restricted

### Observation pre-processing:

- Data assimilation techniques assume spatially independent observation errors → Data thinning/super-obbing procedures are required.
- Thinning strategies tested for wind speed.  
Median of:
  - Whole wind farm
  - Upwind half of wind farm
  - First two upwind turbine rows
  - First upwind turbine row
- Wind direction measurements: turbine yaws and obs from mast downstream (Fig. 2)
- Quality control procedures are part of FDDA and DART

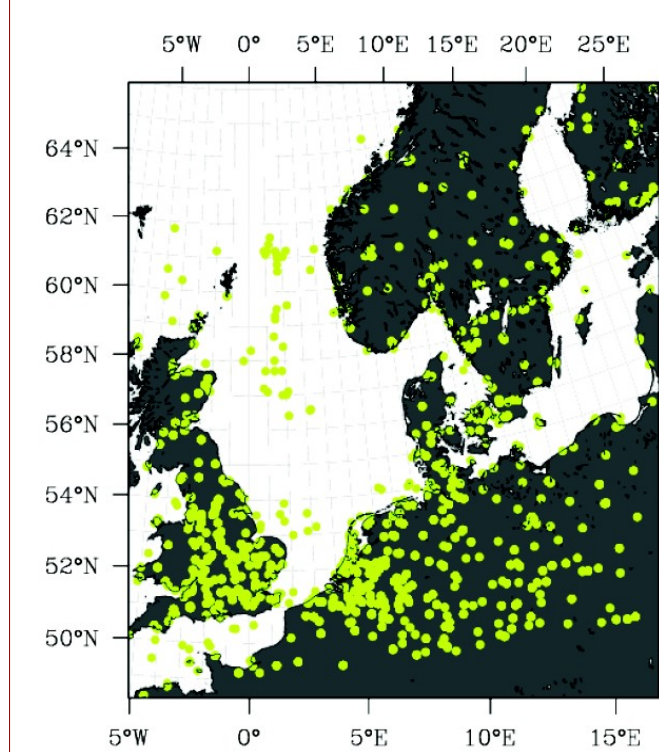


Figure 4: average distribution of MADIS data in the biggest model domain.

WRF-FDDA  
WRF-DART

### Experimental setup:

- Experiments during west wind
- no wake 6 km downstream
- WRF V3.2.1: 3 domains with 30 km, 10 km, 3 km grids
- assimilation every hour

Horns Rev I:  
8x10 turbines covering 19.7 km<sup>2</sup> (4.5x4.4 km)  
Distance between turbines: 560 m  
Distance from coast: 13.8 km  
Measurement mast 6km off downstream of the farm

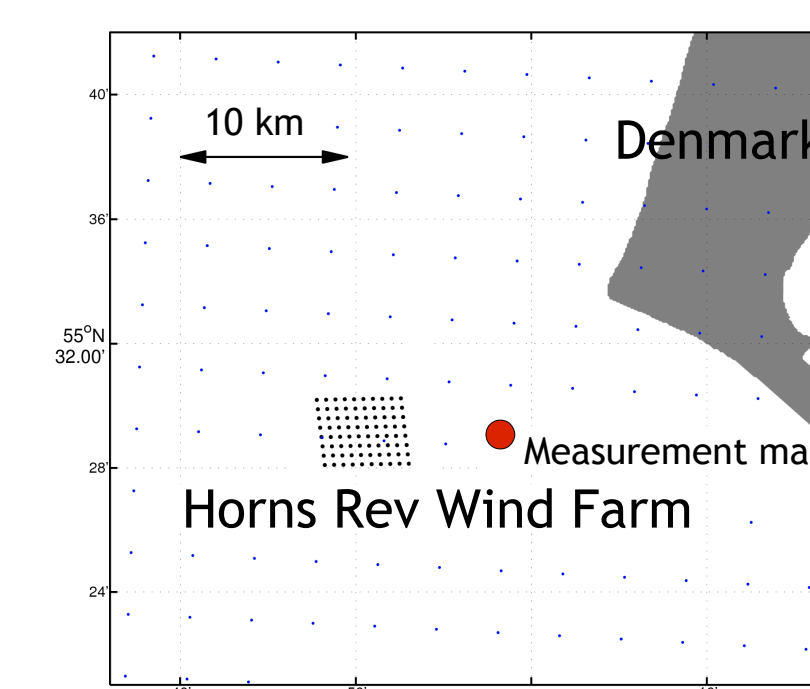
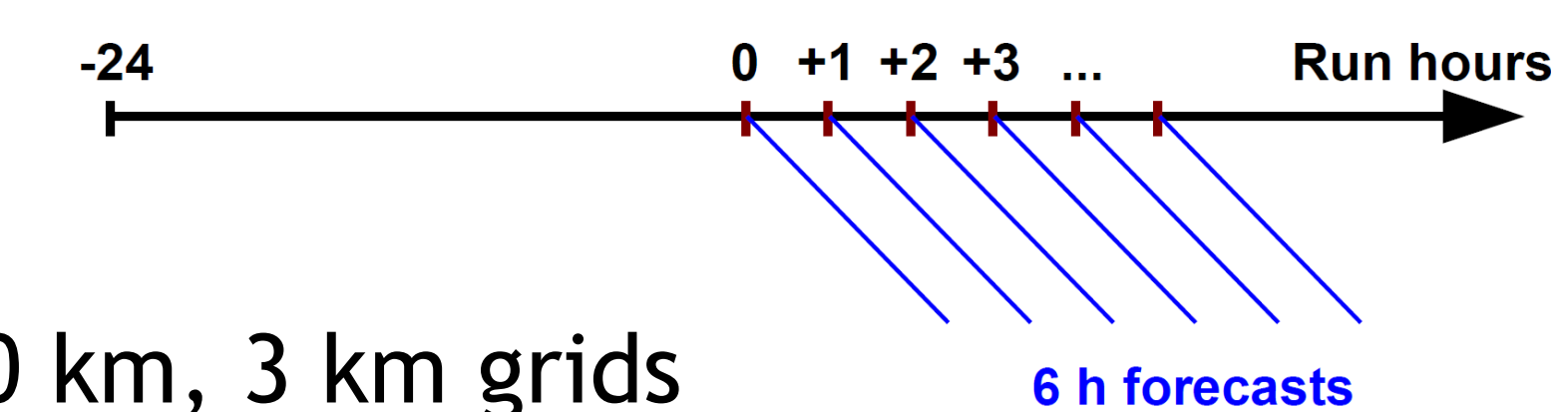


Figure 2: Map of the wind farm Horns Rev and the measurement mast used for comparison. The blue dots represent model grid points.

Figure 1: Schematic of setup of experiments.

Figure 3: Domain configuration and terrain elevation of WRF model setup. The black squares indicate the boundaries of two nested domains. The cross denotes the location of the wind farm.

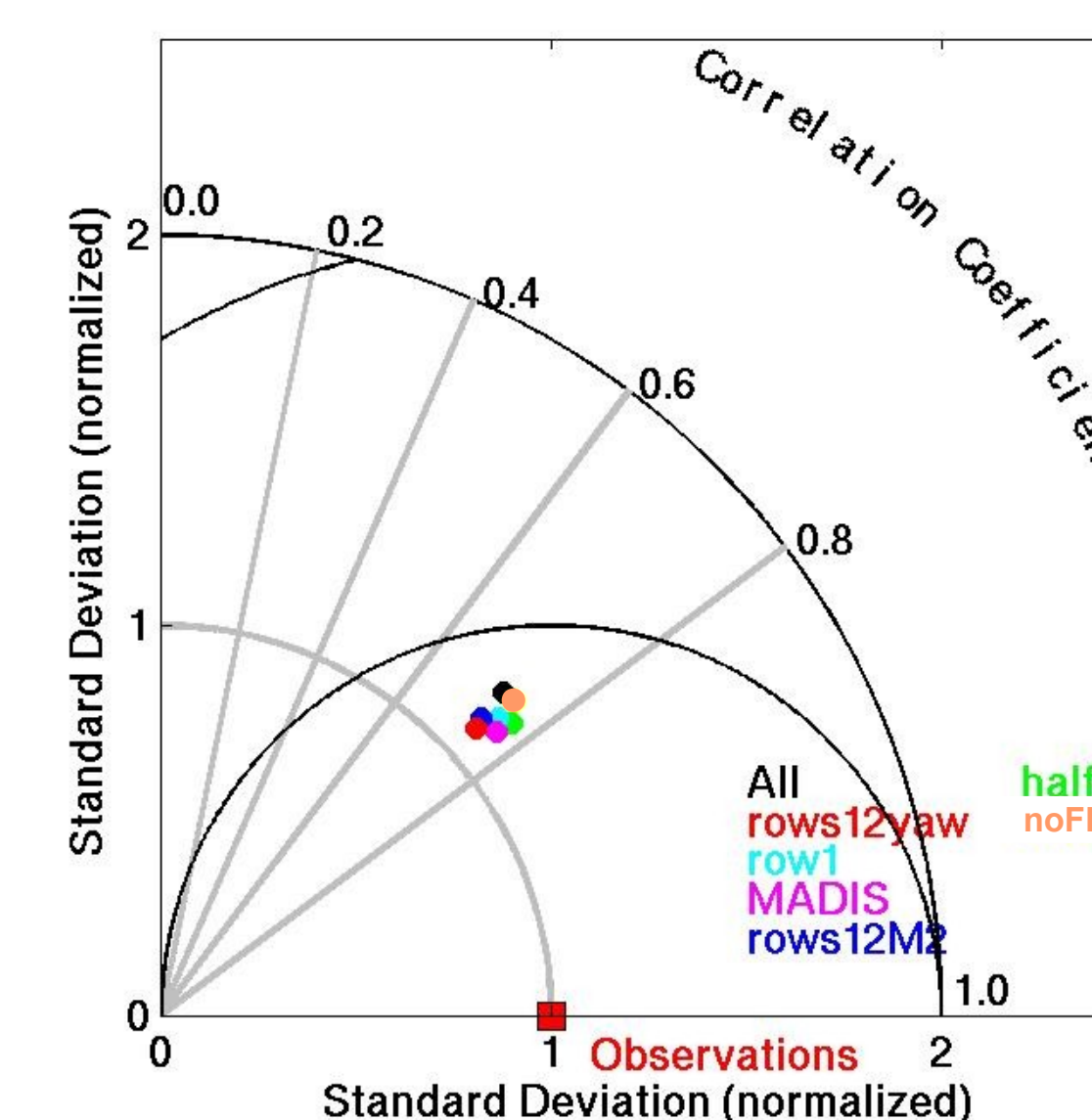
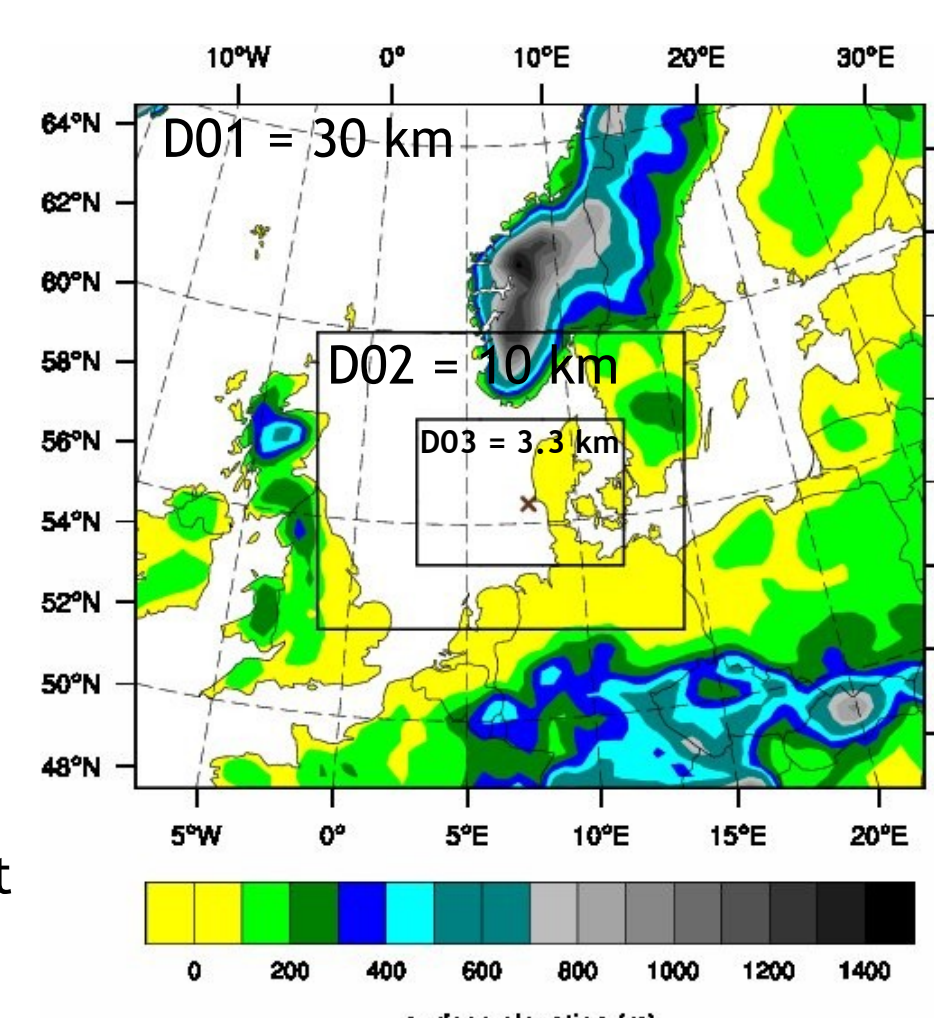


Figure 5: Taylor Diagram for the different thinning strategies for the first lead time.

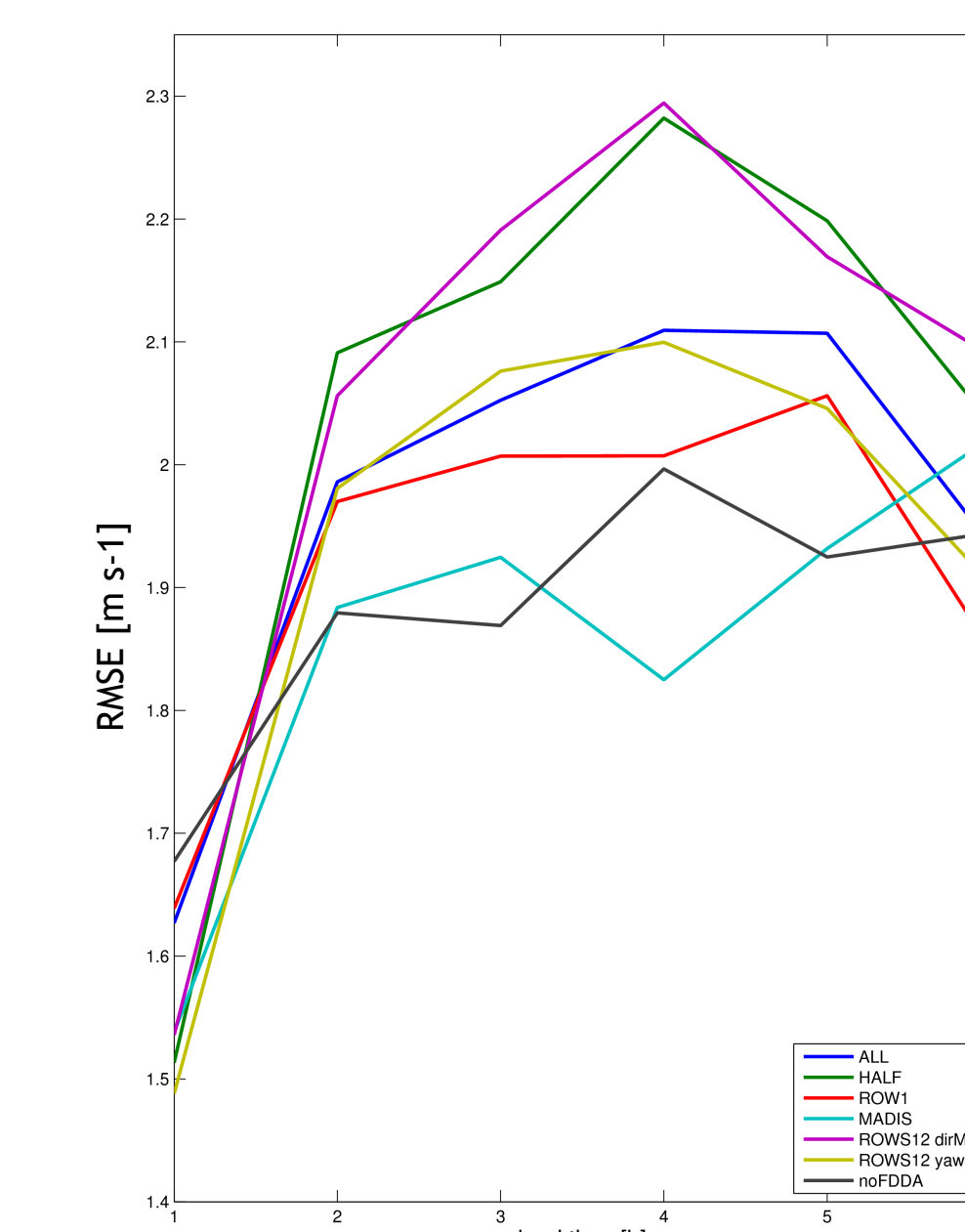


Figure 6: RMSE of wind speed against forecast lead time for the different thinning strategies.

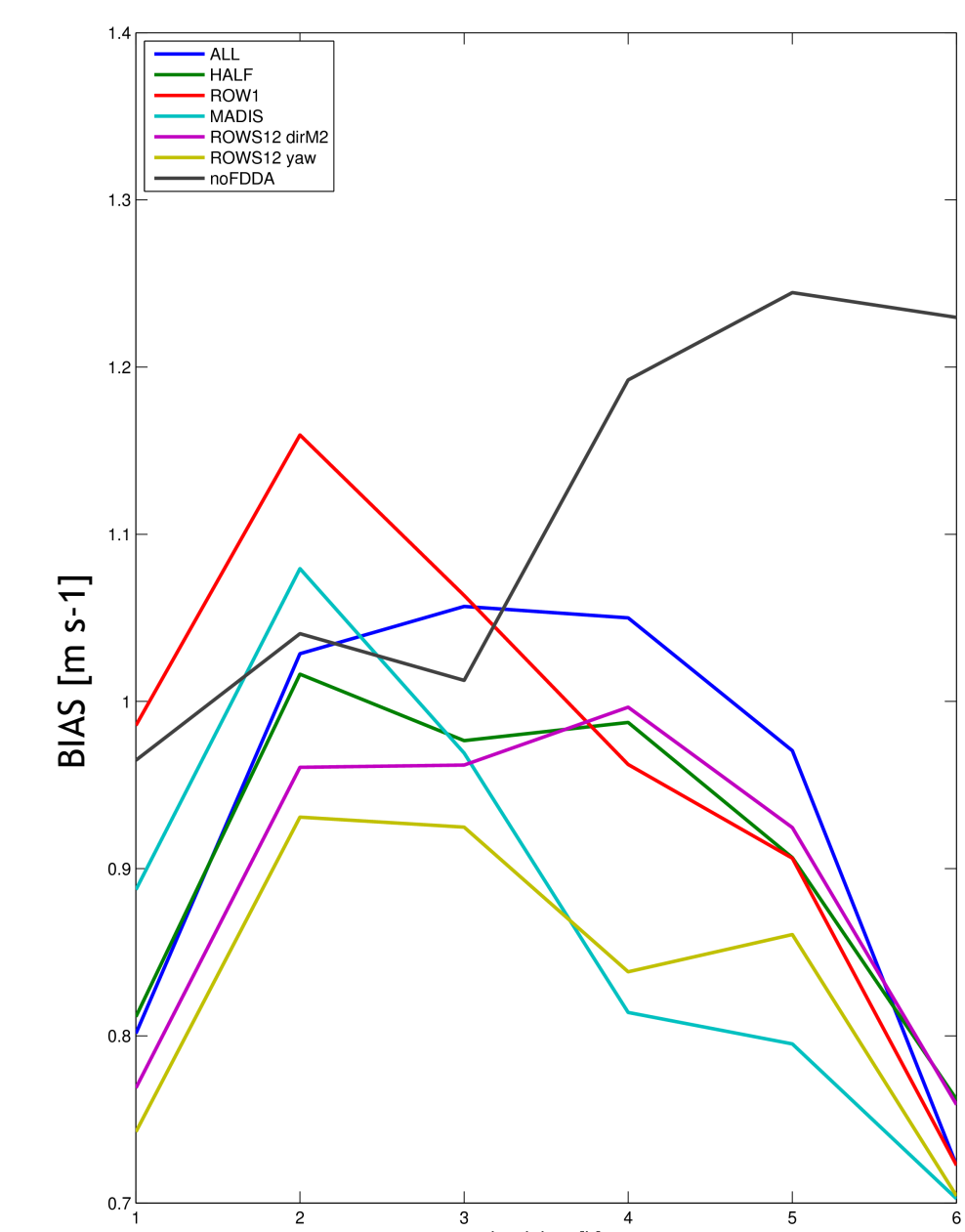


Figure 7: BIAS (model - obs) of wind speed against forecast lead time for the different thinning strategies.

### OUTLOOK:

- compare FDDA assimilation behavior to ensemble data assimilation (WRF DART)
- find causes of performance differences

## Conclusions

- Nudging nacelle winds improves the forecasts for the first two hours.
- It reduces the bias by 17% for the first hour (compared to assimilating only MADIS data).

